INVESTIGATION OF HOOKWORM INFECTION AT THE PING HSIANG COLLIERY, CENTRAL CHINA.

ALFRED C. REED, M. D.,
Assistant Physician, Changsha Yale Hospital.

Several factors have contributed to the belief that an investigation of hookworm infection and the conditions favorable to it in the Ping Hsiang Colliery would yield results of both economic and scientific importance. Among these factors is the paucity of definite and localized studies of the incidence of this disease in central and southern China, together with the well-established fact that the hookworm does occur in these regions. The numerous mines of South Hunan, Kiangsi and the adjacent territory of Kwangtung seemed to offer abundant foci of infection and a possible explanation for the scattered incidence of the disease in these provinces. If any widespread systematic effort is to be made to eradicate ancylostomum in China, the mines, particularly the deeper ones, must receive first attention, according to the analogy of conditions prevailing in other countries.

It is not the purpose of this report to enter on the economic, social or physical significance of hookworm infection. These factors are reasonably as powerful in China as in other countries where further sanitary progress has been made. The abundant literature also cannot be reviewed at this time, nor the history of the disease and of our knowledge of it. For these features, reference is made particularly to the writings of Loos in Egypt, Ashford and King in Porto Rico, and Stiles and his associates in the United States Public Health Service. Within the last four years the situation has been fully reviewed by the Rockefeller Sanitary Commission for the Eradication of Hookworm. The work of the Rockefeller Commission is monumental and the three annual reports so far presented have shown that the disease can be eradicated, as is being done in the United States. The Commission finds that hookworm infection belts the earth in a zone 66 degrees wide extending from 30 degrees south latitude to 36 degrees north latitude. Not one country in this zone is exempt. To summarize, it was felt that investigation of the prevalence and conditions favoring ancylostomiasis in the deep mines of south-central China would be of value because of the known occurrence of the disease in this section, because of the importance of mines in its propagation and spread, and because future efforts to eradicate so serious a disease must be based on definite knowledge of its incidence and strongholds.

With these considerations in mind and desiring to institute studies well within the affected zone, negotiations were opened in January, 1914, between

the Changsha Yale Hospital, located in the capital of Hunan, and Mr. G. Leinung, chief of the staff of German engineers who operate the Ping Hsiang Colliery. The result was a hearty coöperation of the German staff with the Yale Hospital, and a member of the hospital staff was detailed for this investigation which occupied the three weeks from March 25 to April 16, 1914. Many reasons favored the selection of the Ping Hsiang Colliery for this initial investigation. It is the largest colliery in China. Its underground workings are very extensive. The German staff gave every facility and opportunity for the work.

The Ping Hsiang Colliery.

The Ping Hsiang Colliery was started some twenty years ago by Mr. G. Leinung representing the German engineers, and Mr. Chang, representing the Chinese company, on the site of native coal diggings which had existed for an indefinite period before. In two decades the institution has grown to its present size with a daily production of 2,400 tons of bituminous coal. Extensions now being built will raise the output to 3,500 tons within the next six months. Approximately 9,000 persons are on the pay-roll, of whom about 6,900 work underground. The colliery is a branch of the Han Yeh Ping Company, a Chinese organization having its headquarters in Shanghai. This company operates an iron and steel plant at Hanyang across the Han River from Hankow which is supplied with iron from a mining branch at Tai Yeh and with coke from the Ping Hsiang Colliery. The coal above the amount converted into coke is distributed through Hunan and Hupeh.

Geography.

The colliery occupies a charming situation in the valley running east from the large walled city of Ping Hsiang in the western edge of Kiangsi Province. It is located at the village of An Yuen five miles from Ping Hsiang. In spite of the 900 miles distance inland from Shanghai, following the course of navigation on the Yang tza and Siang Rivers, the altitude of An Yuen is surprisingly low. The main adit and main level of the mine is just 500 feet above Shanghai sea-level. The range in which the coal-beds lie varies in height from one to two thousand feet above sea-level. This comparatively low altitude is a factor to be remembered in considering the incidence of ancylostomum.

An Yuen lies on the watershed between the Siangtung River running west into the Siang River in Hunan, and the Siu River running east into the Kan which empties into the Poyang Lake in Kiangsi. Southeast of the village is the range of the Lo Siao mountains in which are the coal fields. This valley, like all the multitude of valleys intersecting it, is solidly terraced with paddy fields, and the paddy field offers a peculiar and

difficult problem when it is infected with hookworm. The colliery is in longitude 114 degrees east and latitude 27 degrees and 30 minutes north. It is located in one of the richest mineral districts in China, namely, the section south of the mid-Yang-tze, including Kiangsi, south Hunan, and the adjacent portion of Kwangtung. In this district are almost limitless coal fields which have been scarcely scratched by the centuries of native mining in those situations where the strata pinch out at the surface. In conjunction with the coal are vast iron deposits, and also limestone, antimony in places, manganese and silver. Natural gas and oil have not been found but thus far no deep borings have been made in this section.

At present the only approach commercially to the Ping Hsiang Colliery is by steamer from Hankow to Changsha or Chuchow in Hunan and thence by railroad sixty miles at the shortest to An Yuen. A British concession, however, has just been granted for a railroad from Ningpo to Changsha by way of Ping Hsiang with a branch midway to Hankow. Such a line will open this great mineral district to aggressive development. Commercial development of the mineral resources, not to mention the social and economic welfare of the inhabitants, will suffer severe damage if practical measures are not taken from the first to combat hookworm infection in this locality. The well-known menace of this disease in mining and industrial regions elsewhere in these latitudes, the extreme difficulty of eradicating it from deep mines, especially where the climate is such as here, and finally the fact to be developed in this report of the high rate of incidence of an ancylostomiasis in the Ping Hsiang Colliery together with its presence to a lesser degree throughout this section, these things together make the question of hookworm infection of central China mines is a problem of the most pressing hygienic and economic concern.

Meteorology.

Accurate meteorological measurements for the entire year at the Ping Hsiang Colliery are not yet available but for February, March and April, 1914, the period immediately preceding and including this investigation, careful records were kept. The average annual rainfall is about 750 mm., the maximum amount falling between February and June. From September to December there is practically no rain. The table of average thermometric and barometric measurements on the next page is compiled from the figures of Mr. Esterer of the Colliery Engineering Staff.

It thus appears that in spite of the fairly low average temperature for the three months of 12.7 degrees, the humidity is very high, a factor of no inconsiderable importance in the propagation of hookworm and other parasitic affections. During these months rather high maximum figures occurred, which again favors parasitic development. The minimal temperatures, which contribute largely to the low average temperature, were

not long sustained and their temporary nature would have small inhibiting effect on parasitic organisms. As February and March are the first two months of the rainy season, high humidity is to be expected but while this helps to explain the atmospheric moisture, it does not diminish its effect on the development of the hookworm and other parasites. For the period included in these observations, the amount of sunlight was about 35 per cent. of the maximum possible if every day had been clear. This was a factor in preventing higher temperatures as well probably as in raising the humidity.

		Thermometer.				Barometer.			
		Dry scale.		Wet scale.		Per cent. relative degree of humidity.		Mm.	
		A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
February	Max.	15.0	21.2	14.0	19.5	93.5	90.0	769.0	759.4
	Min.	4.3	4.9	3.6	4.1	68.5	54.9	748.0	752.4
	Av.	8.1	10.9	7.7	9.1	85.8	78.3	757.2	756.3
March	Max.	21.8	29.0	17.5	21.5	95.5	95.3	764.0	762.5
	Min.	4.0	4.0	3.5	3.3	65.3	41.6	741.0	735.3
	Av.	11.4	15.0	10.7	9.0	86.6	75.1	754.3	750.0
April	Max.	25.6	27.0	20.0	23.0	91.0	90.2	763.2	761.2
	Min.	4.2	4.6	3.5	4.0	57.0	54.5	748.1	745.0
	Av.	13.8	17.1	11.8	13.5	79.7	73.2	755.6	755.3
General Average		12.7		10.3		79.7		754.7	

Note: All temperatures are on centigrade scale.

Water Supply.

The distribution of the water supply of the colliery may be divided among the following heads: 1. Water used in technical processes in the coal-washing plants, which is used over and over again and requires an hourly addition of 5 cubic metres of fresh water. 2. Water used in the coolie bath and boarding houses, amounting to 8 cubic metres per hour. 3. Water used to quench the red-hot coke as it is removed from the ovens, amounting to 5 cubic metres per hour. 4. Feed water for the boilers of the power plant amounting to 16 cubic metres per hour. 5. Water used in the European house for domestic purposes, amounting to .8 cubic metres per hour, giving a total of 34.8 cubic metres of water used hourly above ground by the colliery.

Strange as it may seem, the mountains surrounding An Yuen do not afford available springs or streams from which this large amount of water

may be drawn. The surface waters are used for the paddy fields and no provision exists for gathering and storing rain water. The entire water supply is therefore taken from the mine. As described elsewhere, the further and higher levels of the mine drain off the water which accumulates in the comparatively shallow native mines on both sides of the range. Practically all of the mine water is from this source, as it is only in the general localities where coal-seams outcrop that the levels and drifts of the deep mine approach the surface, and it is also in these localities that all the native mines are sunk. Hence the surface waters very largely drain into the native mines and not directly into the drifts of the larger colliery. The geologic arrangement of the strata of the coal-bearing range likewise tends to make the native mines an intermediary agent in collecting surface waters and draining them into the colliery. The native mines pierce the superficial clay strata which parallel the surface and so lead the water to the out-cropping coal seams immediately beneath. Thus practically all the water in the colliery is derived from that collected by the native mines.

Sanitary conditions are not found in the native mines. The temperatures range very high in them, averaging from 30 to 35 degrees centigrade, due to the small calibre of the shafts, the single bore, the entire lack of ventilation, and the large number of people working in them. Practically every one of the 200 and more native mines in South Hunan and Kiangsi, which furnish the basis for these statements, had at some part a water depth of from 6 to 18 inches through which every coolie must walk every time he entered the mine. Very frequently the calibre of the drift is so small as to necessitate crawling and sliding with a liberal application of dirt and mud to hands, face and neck. The entrance shafts are not vertical but inclined at an angle of from 20 to 40 degrees following the inclination of the coal seam. To allow passage through them a narrow wooden or bamboo ladder is fastened on the earth of the floor of the incline. The rungs of these ladders are characteristically Chinese in their close placement, each step being only from 6 to 10 inches. The ladder is fastened snug against the wet clay floor of the shaft and the coolie tramps heavily up and down at each step pressing his foot firmly into the warm mud under the ladder rung, and dragging after him a basket filled with earth or coal, which slides along the upright side pieces of the ladder. These features of the native mines and their relation to the Ping Hsiang Colliery are discussed in detail for two reasons. First, is their important and intimate bearing on the question of water supply and hookworm infection of the colliery. Second, is the very grave question of the degree of incidence of the hookworm in the native mines and the very serious problem of its eradication there. It will not be possible to eliminate hookworm infection from central and southern China so long as such ideal culture beds as these native mines are left as constant and productive foci of infection.

There is every reason to believe that in the native mines the incidence of ancylostomiasis is very heavy. The close relation by drainage between these mines and the large colliery, and the fact that practically all the water in the colliery is from this source, suggests the probability of a constant fresh infection of the colliery from the native mines as well as a constant pollution of the mine water of the colliery from fecal and urinary contamination in the native mines. Further investigation of this point would be a reasonable procedure.

The water of the colliery is not only subject to chemical, bacterial and entozoal contamination at its source, but it suffers most serious pollution in the colliery itself. At least 2,500 coolies are constantly at work underground, and their urine and feces are indiscriminately and quite thoroughly spread through the mine. Especially in the upper and wetter levels is this of the utmost importance because the water and soft mud on the floors of many drifts are being constantly churned by the bare feet of hundreds passing. The fecal material is thus intimately mixed with the thin mud and widely distributed even outside the mine by the mud adhering to the coolies' feet and clothing. In view of the darkness and high temperatures, a more ideal arrangement for the propagation and dissemination of the hookworm and similar affections could scarcely be conceived.

The chemical condition of the mine water is shown in the table on the following page giving a complete chemical analysis of the waters from the main adit, and from the shaft, compared with the figures for an average normal drinking water.

As would be expected the total hardness of the water is high—between two and three times the average normal. It is to be noted that the magnesia fraction of this total hardness is especially high and clinical experience bears out the theoretical conclusion that, used for drinking purposes, this water predisposes to diarrheal conditions especially in new-comers. In the tropic heat of summer this might well increase the danger from dysentery and typhoid germs, pathogenic amœbæ and other intestinal parasites. The high proportion of chlorine and the presence of nitrates and traces of ammonia clearly indicate urinary and other organic contamination. These substances naturally are not dangerous in themselves but their presence strengthens the probability of accompanying dangerous chemical and biologic bodies.

Referring again to the uses to which the mine water is applied it is evident that in its employment in technical processes the only sanitary danger is incidental. The chance for infection with hookworm lies chiefly in the accumulation of more or less wet coal-dust and mud on the floors on which the bare-foot coolies are at work and in the hand labor of picking extraneous matter from the coal as it passes along an inclined chute. In the use of the water in the coolie bath and boarding houses and in the hos-

pital a much more serious situation appears. The bath and boarding houses are described in a later paragraph. The infected and dirty water from the mine is in part heated before being sent into the bath-houses, so that it is improbable that many hookworm larvæ are brought in by the water supply, but all unheated water may with reason be subject to suspicion.

The same holds true for the use of mine water for bathing purposes in the hospital and also for its use for domestic purposes in the houses of the foreigners. It is improbable that the affection spreads to any extent through drinking water. The Chinese drink almost no water and in the preparation of the omnipresent tea the water is boiled, a fact that without question has made no small contribution to the longevity of the race. The foreign staff, too, uses drinking water with the utmost moderation and while this is not universally boiled as it should be, the meagre quantities used minimizes the dangers of hookworm infection. The fact that of the foreigners examined, only those were infected whose work took them

WATER ANALYSIS BY MR. ESTERER.

Calculated as grams per litre.

Item.	Shaft water.	Main adit water.	Pure drinking water.
Total residue	0.8361	0.5442	
Residue after boiling	0.6703	0.4345	
Suspended matter	0.0503	0.4122	0.
a. Organic	0.0123	0.1941	
b. Inorganic	0.0380	0.2181	
Silicic acid	0.0160	0.0160	
FeO and Al_2O_3	0.0038	0.0028	
So_3	0.5429	0.1475	0.0600
Chalk (CaO)	0.2160	0.2476 } See hardness	
Magnesia	0.1501	0.0993 }	
N_2O_3	0.0003	0.0001	0.0000
N_2O_5	0.0006	0.0005	0.0200
Ammonia	0.0000	Trace	0.0000
Chloride	0.0148	0.0174	0.0010
Permanganate-binding	0.0136	0.0089	0.0600 to 0.0100
Permanent hardness	19.2 degrees	8.2 degrees	
Temporary hardness	14.7 degrees	22.4 degrees	
Total hardness	33.9 degrees	30.6 degrees	8 to 12 degrees
Reaction	Neutral	Neutral	
Odor	Stale	Stale	
Appearance of filtered water	Slightly yellow	White-clear	

constantly into the mine, tends to show likewise that drinking water infection is uncommon to say the least. However the possibility of such infection is certainly present as well as that of typhoid, dysentery and other diseases. A new water system is now being installed which will secure water from a purer source and store it in a screened and locked reservoir from which it will be piped to each house. All of the water for drinking and bathing alike for foreigners and Chinese will pass through coke filters and will undergo a softening process which will in large degree eliminate the dangers of the present water supply.

General Lay-Out of the Mine.

As has been stated, entrance to the mine is twofold—by way of the main adit going straight and horizontally into the mountain from the floor of the valley, and by way of two shafts, 300 and 500 feet in depth respectively. The shaft division is the part originally worked and is smaller in extent and output than the section tributary to the main adit. It includes only the deeper parts of the coal seams below the level of the valley and the main adit. The bulk of the mine, reached through the main adit, is above the level of the valley floor, and comprises four levels above the main level, each with its numerous lateral drifts following in each seam. The fourth level is near the summit of the range and egress could easily be obtained from it at many points.

The main adit is 2,500 metres in length and is traversed by a double and in some parts a sextuple tracked electric tramway, which incidentally is the oldest electric railway in China. The coal seams are in three groups which are successively pierced at right angles by the main adit. These groups are parallel and are inclined at an angle of 20 degrees to the main adit. Where the adit pierces the nearest and thickest group of seams, is the junction with the main level of the mine which runs in the seam transversely to the adit, with lateral drifts following the seam up and down according to its inclination. This main level is 2,000 metres from the entrance to the mine. Five hundred feet further is the third group which has been worked out.

The seams are thus all transverse to the main adit and inclined upward and away from it at a 20 degree angle. Lateral inclined drifts from the main level and its branches in each seam follow upward in each seam for about 120 metres where it reaches the first level, which runs horizontally in the seam parallel to the main level and in turn has lateral inclined drifts following upward in the seams to the second level. So the plan continues to the fourth and highest level. The average absolute difference in altitude between adjacent levels is about thirty metres.

As practically all the work is done by man labor, these numerous steeply inclined drifts through which materials must be carried assume considera-

ble importance from the abundant moisture, the omnipresent dust and mud and the fact that hands, arms and even head and neck are of necessity brought in contact more or less with the mud and water. This is true for the foreigners, too, and opens a possibility for hookworm infection through the skin of hands, neck and face, even when the feet are well shod.

Below the level of the adit and main level are two deep levels communicating with the main level, but with haulage ways tributary to the main shaft. The mine ventilation is surprisingly good so far as oxygen supply is concerned, there being few points where lamps do not burn freely. The ventilating system depends on the liberation of compressed air which is piped throughout the main drifts, and on the maintenance of a powerful suction of air into large furnaces in two widely separated parts of the mine, whose flues lead to the surface. The ventilation is controlled by the usual system of air-compartments and doors. In spite of the frequent difficulty with mine fires, coal-dust and mine-gas, the system is effective. To it is due the fact that the average temperatures of the mine are not higher. In the lower levels the temperature averages between 23 and 24 degrees centigrade. As the altitude of the levels increases, the temperature rises to some extent until in the upper levels it ranges from 27 to 29 degrees centigrade. For reasons already presented the higher levels are also the hotter ones. Thus moisture and temperature increase together, a condition which would be expected to determine a higher degree of hookworm infection in the upper levels of the mine. As a matter of fact such an increased incidence was not found, but the infection was apparently distributed with considerable uniformity throughout the underground works. This is easily explicable in the light of the following facts. The long period in which the mine has been operated and the frequent shifting of coolies from one part to another, would tend to equalize the incidence. Then too the natural and very rapid drainage from the higher to the lower levels, from which the water is pumped out, unquestionably has an important rôle in carrying the infection from the higher and more favorable levels to the lower sections.

Above ground is an extensive plant also, which includes several units. The coal from the mine goes directly to the two washing plants where it is cleaned, sorted and graded, and where all of the dust is separated for the preparation of coke. The important sanitary features in these buildings from the present standpoint are the imperfect lighting, the apparent necessity for hand-picking of the wet coal and the accumulation of dirt and moisture from the coal as it goes through the building. That these points are not without significance is shown by the fact that a considerable degree of hookworm infection was found here, the incidence being about two-thirds that in the mine. A contributing factor is however found in the occasional interchange of coolies between the mine and the washing plants,

and in the fact that the coolies from the washing plants live in the boarding houses and use the baths of the mine coolies.

Next to the washing plants are the coke ovens and here the only factors favoring dissemination of the infection are the custom of the coolies of using their feet in pushing the wet coal dust from the tram cars down into the ovens, and the fact that in quenching the glowing coke after burning, the coolies stand bare-footed or lightly sandalled in the water as it runs back into the drains. This latter condition is insignificant and the former is easily susceptible to remedy.

The machine shops, foundry, carpenter and pattern shops, smithy, car construction house, and steel-working shop are of considerable size and offer certain facilities for the spread of ancylostomiasis. Chief of these may be mentioned the dirt which adheres to pieces of machinery such as pumps, engines and gearing brought from the mine for repair. This dirt is a potent source of hookworm infection in the shop employees who handle these largely by hand and without any preliminary washing or cleaning. This is the chief etiological factor undoubtedly in the moderately high incidence found in this class of workmen. None of these men live in the company boarding houses. Few if any of them have previously worked in the mine. The shops are across the railroad tracks from the washeries and other colliery buildings, and there is little intercourse between the two sets of employees. Then, too, the proportion of a better class of workmen is higher as the work is more technical, demands greater skill, and is accordingly better paid. The result is a higher scale of dressing with shoes more constantly worn, and a minimum of strictly coolie labor. Viewed with consideration of these circumstances, the infection rate is surprisingly high, and apparently indicates a more general distribution of the hookworm outside of the mine proper, and even of the colliery.

The nature of the work, the conditions under which it is done, and the better character of employees necessary to perform it, decrease greatly the degree of infection in the power and compression plants, the offices, magazine and hospital. In these units the disease occurs chiefly in those whose work takes them at times into the mine. The living conditions of the foreign staff are admirable alike from a sanitary as from an æsthetic standpoint. Their dwellings are placed well up on the mountain side with no cultivated land above or back of them, and with free drainage from the steep slope. The installation of the new filtered water system will even increase the present excellent health conditions and still further reduce the danger from water-borne diseases.

The coolies from the mine and above-ground units exclusive of the shops, live in large boarding houses which are owned and operated by the company. The average expense to the company per man daily for board and lodging is 8 cents Mex. This, as also the oil for lights in the mine, amount-

ing to 4½ cents per 12-hour shift for each man, is furnished by the company in addition to the wages paid. The wages vary from 30 to 40 cents Mex. per day with the nature of the work. There are three large and eight small boarding houses. The large ones are two-story brick structures divided on each floor into large rooms each with a pair of windows at the outer end and the hall door at the opposite end. The sides are lined with tiers of very wide and spacious bunks, 24 in all and each room accommodates 48 men, of whom half work on night shift and half on day shift. Between the bunks is space for tables, chests and stools. From each room one man is detailed to bring from the kitchen the food for the entire group of 24 men, which is eaten in this room. The latrines and baths are in separate buildings.

The conditions in the boarding houses are far from ideal especially in regard to light and air, although on the other hand they are a vast improvement over the conditions under which the coolies would live outside. From a sanitary standpoint, lighting and ventilation are inadequate, the brick floors and walls wear badly, and the general brick construction is unsatisfactory. But the bunk-rooms and boarding houses present no features of special importance for the propagation of the hookworm.

Outside of the large bunk-houses are small brick structures used as latrines. The Oriental habit of the people precludes the use of any western toilet seat, as even when it is provided, the coolie merely squats on top as he has done for ages immemorial and the seat receives more or less of the material intended for the receptacle beneath. The most feasible form of latrine is the one here provided. The floor space of the building is occupied by a brick-walled pit about seven feet in depth, across which are laid heavy planks a foot in width with an interval of some ten inches between. This arrangement reduces to a minimum the soiling of the coolies' feet and clothing with fecal matter, and the level of the planks is above the range of splashing. On the side opposite the entrance, the pit extends perhaps a yard beyond the wall of the building, and to this place come the farmers with their buckets and carry away the material for the fields.

While the arrangement of these latrines is admirable so far as it concerns the danger of spreading hookworm infection among the mine coolies, there is another equally important feature which is not so fortunate. The mixture of feces and urine does not remain long in the latrine but is quickly carried away to the paddy and vegetable fields in the valley. The common pit affords an excellent means of thoroughly mixing the feces from highly infected cases with that from the non-infected, and the result is a uniformly heavy infection of the material which is carried away by the farmers. Thus there is a constant and large stream of hookworm infection from the mine distributed broadcast through the agricultural sections. Not only are measures in order to free the colliery from hookworm im-

portant but it is of the utmost sanitary importance that no source of infection be left open from the mine to the outside country.

Two bath-houses are provided in each of which several hundred men can bathe at once. Especially at the hours when the shifts change these houses are crowded. Their size and ventilation are fair but increased window space is needed. The flooring is of brick with the usual disadvantages of irregular wear and permeability. Across the full width of the floor run parallel brick-lined trenches, each about 2 feet wide and 2 feet 6 inches deep with an interval a yard wide between. These trenches are filled with warm water supplied through small pipes placed just below the surface of the water. The outlet is merely an overflow gutter situated quite close to the inlet. The result is practically no circulation of water in the trenches and the accumulation of an enormous quantity of dirt from the hundreds of bodies begrimed from head to heel with coal dust and mine mud. The quantity of dirt is materially increased, too, by the custom of the coolies of washing their clothing and shoes or sandals in the same water. The excellent chances afforded for disseminating hookworm and other infection is apparent. This system was inaugurated when the coolies wore long hair and a queue but in the days of the republic coolie heads are close cropped or shaven as a rule, and the former objection to shower baths is not so valid.

The kitchens are in good sanitary condition, the food is well-cooked, of suitable variety, and sufficient quantity. The food served here can be excluded as a source of hookworm infection. This does not however hold true in the mine where the coolies eat their midnight and midday meal, and where mudstained hands and dirty clothes used to wipe out the dishes may easily infect by ingestion. The general location of the boarding houses is excellent, on a fairly steep mountain slope, on sandy soil with good drainage, and exposed to a strong and fairly constant breeze.

Incidence of Ancylostomum.

In these examinations ordinary smears were made covering about three-fourths of a 1 x 3 inch microscopic slide. No cultural or concentration methods were employed nor was any record kept of the results of treatment. In those cases which were treated, thymol was used in the manner recommended by Stiles for the Rockefeller Sanitary Commission. In all those cases in which examination was made for the worms the ancylostomum duodonale was found. Stitt (*Practical Bacteriology and Parasitiology*, 1913, p. 266) quotes the claim that where the ordinary microscopic examination for ova shows 40 per cent. infection, and concentration methods 55 per cent., cultural methods will show 99 per cent. infection. This should be recalled in the light of the figures presented here.

In the course of this study examination was made of 272 persons, of whom 225 were workers in the underground section of the mine, 19 were from the washing plants, 11 from the machine shops, 11 from the foreign staff and families, and 6 were from the valley outside the colliery. Table A shows the result of this examination. Of the 225 coolies from the entire underground works, 90.2 per cent. were found infected with hookworm, 64 per cent. with ascaris lumbricoides, and 8 per cent. with trichocephalus dispar. In no case after the hookworm ova were found was the search continued for other parasites. The figures for ascaris are therefore minimal and there is reason for believing that ascarides were actually present in from 95 to 100 per cent. No relation was found between infection with ascaris and with hookworm. The different sections covered the entire range of the mine in temperature, moisture and elevation, yet there is no significant difference in the percentage of infection, the range being from 100 per cent. in 9 sections, to 66 per cent. in the third shaft section. This latter low ratio is based on a total of but three cases and cannot weigh as an absolute figure. In those sections from which ten or more men were examined, the lowest incidence was 73 per cent. It is to be remembered also that in none of the cases reported negative, was the search extended beyond three slides and thirteen minutes. In view of the high ratio in many sections and the probability of and facilities for a uniform infection throughout, it is certain that the figures here presented are minimal, and it is most probable that corrected figures would be much higher throughout.

In the light of the points recorded in describing the above-ground units of the colliery, it is interesting to note in the washing plants an incidence of 50 per cent. and in the machine shops an incidence of 27 per cent.; figures which harmonize closely with conclusions drawn from the study of sanitary conditions in those units. Of the 11 members of the foreign staff and their families examined, three, or 27 per cent., were infected. These three were engineers whose daily routine required the supervision and inspection of underground work. No case was found in a foreigner who did not regularly visit the mine. Of the six cases examined from outside the colliery, two were infected. This proportion would be expected to hold for much larger numbers, as the chances for infection spreading from the mine to the surrounding country are abundant. These chances lie chiefly in the migration of infected coolies from the mine to other occupations outside, the use of infected sewage from the colliery as a general agricultural fertilizer, and the transportation of infected mud from the mine by various means. Of the entire 272 persons examined, a total of 222 or 81.6 per cent. were found infected with hookworm. Of the 36 persons outside of the mine proper, exclusive of the foreigners, 16, or 44 per cent., were infected.

TABLE A.

Section of colliery.	Total no. examined.	Hookworm positive.	Per cent.	Ascaris l. positive.	Per cent.	Trichocephalus.
Main Adit No. 1.....	10	10	100	8	80	
Main Adit No. 2.....	5	4	80	4	80	1
Main Adit No. 3.....	10	10	100	6	60	
Main Adit No. 4.....	15	14	93	6	40	2 Oxyuris 1
Main Adit No. 5.....	25	25	100	18	72	4
Main Adit No. 6.....	19	19	100	14	73	2
Main Adit No. 7.....	28	24	85	17	60	2
Main Adit No. 8.....	9	9	100	6	66	
Main Adit No. 9.....	15	11	73	10	66	1
Main Adit No. 10.....	1	1	100	1	100	Amœba 1
Main Adit at large....	21	16	76	15	71	1
Shaft No. 1.....	3	3	100	2	66	
Shaft No. 2.....	3	2	66	2	66	
Shaft No. 3.....	11	11	100	8	72	
Shaft No. 4.....	4	4	100	2	50	
Shaft No. 5.....	11	10	90	9	81	Ascaris C. 1
Shaft at large.....	13	10	77	10	76	
Mine at large.....	22	20	90	7	33	
Totals for mine.....	225	203	90.2	145	64	18.8 per cent
Washing plants.....	19	11	57	14	73	1
Machine shops.....	11	3	27	10	90	
Outside.....	6	2	33	3	50	1
Foreigners.....	11	3	27	0	0	
Grand total.....	272	222	81.6	172	63	20.7 per cent 3 Unidentified

In the case of routine examination, one case each was found to harbor oxyuris, ascaris canis, and amœba. Three unidentified ova were observed. A rich field is here for the study of rare entozoa.

A study of the clinical effects of ancylostomiasis in the mine coolies presents many difficulties. The general physical average is far below a similar average for European or American miners and where the European miner averages one ton of coal per day output, the Ping Hsiang miner averages less than half this amount. Practically all of the coolies show some physical abnormality. The average coolie is undersized, short, under normal weight for height, pallid, stooped and unsymmetrically developed. This general poor physical condition cannot be laid at the door of the hookworm, because the mine coolies are constantly being recruited from the farming districts of the provinces close by, and are presumably not infected in a

large proportion when they come to the colliery, and also because a similar proportion of poor physique is found elsewhere and in other strata of society. Complete physical examination and measurements were made by the physical department of the Yale College in China of 112 students between the ages of 14 and 21. These men were drawn from the best Chinese families and are presumably the best physical stock that central China can produce. Among them no hookworm was found, yet 25 per cent. showed poor general physical condition, 53 per cent. fair, and but 22 per cent. were in good condition. The system was the same as at Yale University.

The hookworm alone therefore cannot be charged with entire responsibility for the very poor general physical condition of the coolies of the colliery. That the disease is, however, a strong contributory element, admits of no doubt. It is unnecessary here to discuss in detail the influence of hookworm infection on concurrent and sequent disease conditions and on economic efficiency. Suffice it to say that a considerable proportion of the invaliding at the colliery must be due indirectly to this cause. Pulmonary tuberculosis is here as always the scourge of China, and the readiness and speed with which it develops and spreads are explicable in the light of the hookworm incidence. The weakened vitality and lowered threshold of infection due to ancylostomiasis not only cut down the daily output of coal per man but they pave the way for an extremely high rate of disease incidence and mortality. A consideration of no mean importance is the havoc which epidemic disease would make should it once gain a foothold under such circumstances.

In spite of these indubitable facts, Table B shows that exactly the same percentage of the 77 cases examined from the colliery hospital were infected with hookworm as of the 187 cases examined directly from their work in the colliery. In each case the incidence is 80 per cent. This fact is not to be explained by the assumption that hookworm disease has no direct

TABLE B.

	Total examined.	Hookworm.	
		Positive	Per cent.
Hospital	77	62	80.5
From work	187	151	80.7

influence in determining a higher disease incidence, but rather indeed by the supposition already referred to, that in the underground works the infection is nearly if not quite universal and hence no valid comparison is

possible between hospital patients from the mine and the coolies actually at work in the mine with regard to their relative infection with hookworm. Rather a comparison must be drawn between the incidence of disease in general among the mine coolies and among a corresponding group of farmers, artisans and tradesmen outside the mine, in relation to the hookworm as a predisposing factor. The incidence of disease in general in the miners is distinctly higher than outside but exact comparative figures cannot now be given.

TABLE C.

Infection by Ages.

Age.	Plus.	Minus.	Per cent. plus.
Less than 10	0	1	
10–19	16	4	80
20–29	90	19	82
30–39	81	10	89
40–49	24	7	77
50–up	5	1	83

TABLE D.

Native town.

Town.	Positive.	Negative.	Per cent. positive.
Ping Hsiang	101	12	89
Siangtan	45	9	83
Liling	40	8	83
Hupeh	27	7	80
Liuyang	29	3	90
Hengshan	7	2	77
Changsha	7	1	87
Scattered	10	6	62

In Table C is shown the incidence of hookworm disease by ages, each decade being grouped separately. No significant variation is found nor is there any reason here for regarding age as influencing at all the relative degree of infection. The same may be said of Table D, showing the incidence according to the native towns from which different groups of coolies come

The important factor is not the precedent condition or place but it is simply the fact of employment in the mine. Table E shows the relative incidence according to the length of employment in the mine and again no conclusions can be drawn as the figures are on the whole comparatively uniform and show no relation between length of employment and infection. Even in the first month positive cases appear and this might be assumed to support the view that ingestion of the ova in the mine with the food is a common and frequently repeated proceeding. These tables all indicate that a detailed and complete cultural examination would show an almost universal underground infection.

With the exception of three cases in which three slides were prepared, only one or two slides were examined. Of the total number of cases examined, 77 per cent. showed hookworm ova on the first slide and on the first slide were found 95 per cent. of all the positive cases (Table F). On the second slide 3.6 per cent. of all examined were positive, and 4.4 per cent. of all the positive cases were on the second slide. Remembering the customary infrequency of hookworm eggs in positive cases examined by this method and the fact that in none of these cases was a preliminary purgative employed, it is apparent that the infection must be heavy in a majority of the cases. Stiles recommends the examination of ten slides, taking one hour for the task before a definite negative opinion can be given. Here the indications are that such a procedure would have given a percentage positive approaching very near 100.

TABLE E.

Time in colliery.

	Positive.	Negative.	Per cent. positive.
1 month	4	0	100
2 months	11	2	84
3 months	8	2	80
4 months	1	5	16
5 months	3	0	100
6 months	5	0	100
1 year	16	6	72
2 years	28	5	84
3 years	34	4	89
4 years	7	4	63
5 years and over	101	12	89

TABLE F.

Slides examined.			
Slide number.	Positive.	Negative.	Per cent.
1	212	5	95 per cent. of all positive 77 per cent. of all examined
2	10	43	4.4 per cent. of all positive 3.6 per cent. of all examined
3	2	1	

Reviewing the number of minutes per examination necessary to find the first hookworm egg (Table G), it is seen that in one out of every ten cases, an egg was in the first field brought into focus. The largest percentage, 32 per cent; were found within one minute and 83 per cent. were found within five minutes. In no case was the search prolonged beyond thirteen minutes.

TABLE G.

Time of examination.			
Minutes.	Positive.	Negative.	Per cent. of total positive.
0	22	0	10
1	49	0	22
2	37	0	17
3	40	0	18
4	18	0	8
5	12	0	6
6	11	1	4
7	11	0	4
8	3	3	1
9	6	6	2
10	8	13	4
11	3	11	1
12	3	14	1
13	0	3	0

Other Disease Factors in the Mine.

Certain other disease factors are present in the Ping Hsiang Colliery whose importance lies not so definitely in the propagation of ancylostomum as in other lines. Here may be cited the innumerable rats which infest the mine. All of the underground passages require heavy timbering, and where drifts are directly in the coal seams, a layer of pine twigs, ferns and straw is placed directly against the coal and sand to prevent the dust from drifting in and starting excavations of increasing size. This fine brush is supported by the timbering and furnishes first-rate nesting facilities for the rats. The rats exist in enormous numbers. The moisture, darkness and warmth are favorable to them and they subsist on the innumerable cockroaches, the leavings of the coolies' food and the fecal material. The rat question would assume primary importance in the event of the introduction of plague, and here where this danger is always to be feared, rat eradication should be among the earliest sanitary measures to be inaugurated.

Numerous ants worry the miners and large scorpions are found although stings from the latter are seldom reported. Worthy of special investigation is a peculiar dermatitis which is of comparatively frequent occurrence among the mine employees and which is ascribed to contact with the water in certain sections of the mine. The causation is quite unknown although a chemical irritant is probably at fault. As the coolies leave the mine they come from the various hot and humid laterals to the electric tramway of the main adit, which carries them at a high speed for the 2,000 and more metres to the surface. The coolies are half-naked, tired with a long twelve-hour shift and over-heated. The chilling from the fast ride to the surface easily conduces to decrease their body resistance and predisposes to respiratory and enteric affections. In many of the hotter drifts the coolies work naked and practically everywhere they are barefooted or at most shod with rough straw sandals. Thus every opportunity is afforded for the hookworm larvæ to penetrate the skin, not alone of the feet and hands but of the entire body. No particular attention is attracted by ground-itch or analogous conditions but the great frequency of eczemas, furunculosis and minor ulcerations strongly suggests that many of these latter conditions may conceal or spring from a precedent larval puncture of the skin. Again the extremely large number of cut and contused hands and feet affords great chance for larval entrance.

Recommendations.

There can be no question of the desirability from the standpoint of the company and the coolies, as well as of the surrounding country, of eradicating hookworm infection from the Ping Hsiang Colliery. In the way, however, of accomplishing this eradication are certain difficulties hard or im-

possible for one to appreciate who is not familiar at first hand with local Chinese conditions. These difficulties may be briefly capitulated as follows. Money for sanitary improvement is sadly lacking in China today and only definite proof of definite financial advantage is apt to evoke it. Human labor and life are the cheapest commodities purchasable in the open market and there is no public sentiment, and but little private, tending toward a better state of affairs. The foreign staff at the colliery will use every means at its power to improve sanitary and social conditions among coolies but it remains to be seen what can be accomplished against the conservative and indifferent *laissez faire* of the Chinese officials. The company is not in sound financial condition and money for sanitation is therefore the harder to expect.

Again the Chinese coolie and his guild are a law to themselves and with the profound and supercilious scorn of complete sanitary ignorance, regard with indifference, derision or suspicion much of what is attempted in the way of sanitary improvement and health conservation. Conditions would be easier if the company could control its employees and force them to follow instructions. Unfortunately this happy condition does not obtain and outside of the actual mining operations, the company has only nominal control. In view of these circumstances therefore, sweeping changes are out of the question, and the problem must be approached absolutely from the standpoint of what is practical and really possible. Sanitary reform in China is a matter of generations and the eradication of hookworm disease from the deep mines in general and from the Ping Hsiang Colliery in particular, will be no whit easier than the same job has been in the mines of western lands, but on the contrary far more difficult and time-consuming. The following recommendations are made with the above sketched conditions sharply in mind, and after deliberate consideration of the various possibilities.

1. Education is necessary at two points. (1) Education of the head-men of the gangs and sections of the mine. This should take the form of the presentation in informal lectures of the nature and cause of hookworm disease, its economic and individual significance, its history in other lands, and the means of curing, preventing and eradicating it. These lectures should be accompanied by lantern pictures illustrating every point discussed. The lecture system should be accompanied and followed by a direct appeal to the head-men to coöperate with the company in the effort to eradicate the disease, and their coöperation should be made practical by making them responsible for the institution of the measures hereafter described. (2) Education of the coolies by simpler illustrated talks given in the barracks by Chinese assistants, and by distribution of printed matter stating in very plain language what the disease is, how it spreads and how it may be prevented and cured.

2. Division of the mine into about thirty sanitary districts with the native head-man over each responsible for carrying out certain definite procedures in it. Each mine section could be divided into two sanitary sections with the regular native officials in charge as sanitary officers. About five sanitary sections should be combined under a higher official who would act as general sanitary inspector with general supervision over his district. The sanitary inspectors should report to and be directly responsible to the foreign mine physician for the sanitary condition of their respective sections. The mine physician should coördinate and regulate the sanitary measures taken throughout the mine.

3. Posting of numerous plainly-worded Chinese bulletins on hookworm disease, at all points in the mine where coolies congregate, in the boarding houses and other effective places. Posting in the mine as well as in the boarding houses of the definite rules described in the next section.

4. In the mine, buckets should be placed at frequent intervals for feces and urine, and the use of these alone should be strictly enforced by the sanitary staff. Frequent inspections of every part of the mine should be made by the mine physician with a view to securing strict enforcement of this rule as well as to devise new and special measures for localized conditions. The latrine buckets should have a suitable disinfectant put in them and should be carried out of the mine on special cars twice in each twenty-four hours and emptied into the boarding house latrines, scalded, disinfectant replaced, and returned to the mine. Disobedience of the strict rule against defecation elsewhere than in the buckets provided, should entail a definite fine to be deducted from the pay, and in cases where the particular offender cannot be determined, should be assessed against the sanitary section in which it occurs.

5. A system of regular examinations should be instituted covering all persons enrolled with the colliery. The writer demonstrated the feasibility of examining fifty men per day for hookworm infection with the aid of a properly trained Chinese staff, in addition to supervising the usual routine of the hospital. Even the microscopic work can be delegated to a suitable assistant after a time. All positive cases should receive treatment during the half day they are at the hospital for examination. This would best be conducted by administering Epsom salts to all and examining the resultant stools for ova. Positive cases could then immediately receive half of the total degree of thymol, and two hours later the second half. The final dose of Epsom salts could be taken after returning to the barracks. Each person examined should receive a dated certificate stating the result and whether treatment had been administered. These certificates should be checked up by the sanitary inspectors in the mine, and those not having them should be fined. This system would easily allow a complete round of the employees twice yearly and would afford a most valuable means of eliminat-

ing the disease. All new employees should be examined before entering service.

6. In addition to the required examinations, all infected hospital patients should be treated as well as all persons who apply for treatment in the daily clinics.

7. The same system of sanitary supervision should be instituted in the above-ground units as in the mine.

8. The boarding house latrines should be enlarged, and be made the depository for all buckets and containers of fecal material from the mine and above-ground works. The shape and arrangement of the latrines at present is satisfactory but each should be double, having a solid partition wall extending from the floor of the pit to at least six feet above the ground-level floor. Each side of the house should have its own entrance and the pits should be cement lined. The two sides should be used alternately and never at the same time. During the week or such interval as one side is in use, the opposite side should be closed and converted into a septic tank for the disinfection of the fecal and urinary matter and the destruction of hookworm ova and larva. After such a period as may be necessary to accomplish this, as determined by exhaustive bacteriological and microscopic examinations, the back of the closed pit should be thrown open to the farmers as at present, and the entire contents removed. This pit should then be opened as a latrine and the opposite one closed and treated in a similar manner.

9. The bath-houses should be remodelled, the brick floors and trenches being replaced by a cement floor with a concave curve from side to side, and an efficient drainage slope from end to end. Over this should be laid a floor of wooden or metal gratings which could be taken up for scrubbing and scalding at frequent intervals, permitting also thorough flushing and cleaning of the underlying cement. Water should be supplied at a definite temperature from overhead pipes. Low wooden benches can be placed under the showers if desired and clothes racks around the walls.

10. Machinery taken from the mine to the shops to be repaired should be thoroughly washed before leaving the mine.

11. Accurate statistical and progress records should be kept by the mine physician covering every phase of sanitary activity.

Conclusions.

1. The geographical location, geological formations and meteorological conditions at the Ping Hsaing Colliery are decidedly favorable to hookworm infection.

2. The native mines, from which the water supply of the colliery is drained, are undoubtedly heavily infected, and are a potential source of danger to the colliery, and probably an actual danger. Investigation of the

conditions affecting hookworm infection in the native mines is urgently necessary.

3. Conditions in the underground works of the colliery are highly favorable to the propagation and dissemination of hookworm infection, in the particulars of excessive moisture, high temperatures, darkness, constant re-infection by promiscuous defecation, the habits and clothing of the coolies, and the lack of special provisions for sanitary control.

4. Examination of 272 persons showed a general incidence of 81.6 per cent. Of the 225 who worked underground, 90.2 per cent. were found infected. The ratio of incidence was much less in the above-ground works and the infection was also found present entirely outside the colliery.

5. Evidence is deduced indicating that the 90.2 per cent. infection in the mine is a minimal figure and that the true figure approaches 100 per cent.

6. The only factors determining the rate of incidence are conditions in the mine itself.

7. Eradication will be peculiarly difficult and slow but can be accomplished along lines here recommended.

8. This study indicates forcibly the need for intensive investigation of hookworm infection in Hunan, and Kiangsi Provinces, where the disease is apparently a largely unsuspected factor in economic industrial and social ineffieciency.

NOTE: The writer is indebted for much of the information presented, particularly in respect of the native mines and the technical features of the Ping Hsiang Colliery, to the kindly and courteous assistance and coöperation of Mr. Leinung, Mr. Esterer, and Mr. Schlifter, of the German Engineering Staff of the colliery.